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(71) Applicant: International Business Machines Corporation
Old Orchard Road
Armonk, N.Y. 10504(US)

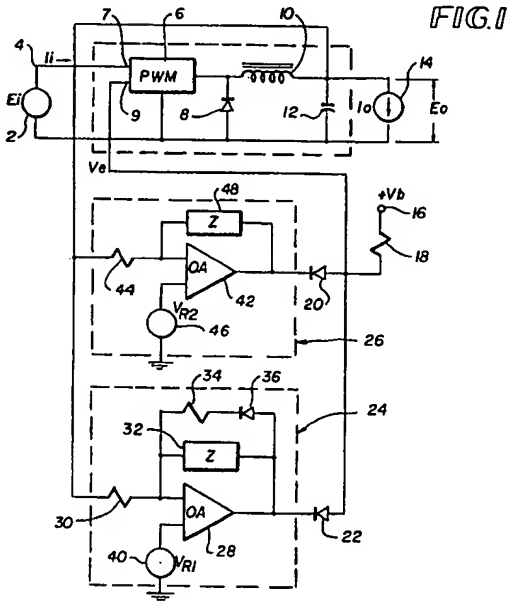
(72) Inventor: Carroll, Lawrence B.
629 Sunset Drive
Endwell, N.Y. 13760(US)
Inventor: Willis, Scott C.
606 Barnes Ave.
Endicott, N.Y. 13760(US)

(74) Representative: Gaugel, Heinz, Dipl.-Ing.
IBM Deutschland GmbH Schönaicher
Strasse 220
W-7030 Böblingen(DE)

(54) Buck switching regulator with two control loops.

(57) A voltage regulation apparatus wherein changes in load current (Io) are not rapidly reflected in the input current (Ii) said apparatus comprising:
a power source (2) for providing an input current (Ii), means (6) having a controllable duty cycle for pulse width modulating the input current (Ii) at a preselected frequency, filter means (10, 12) connected to the output of the means (6) for pulse width modulating, which removes the preselected frequency, a load connected to the output of the filter means (10, 12), a load voltage (Eo) appearing thereacross, first feedback means (24) responsive to the load voltage (Eo) for controlling the duty cycle of the pulse width modulator (6) so as to regulate the load voltage, said first feedback means (24) having a relatively long time constant so that changes in the load current (Io) are not rapidly reflected in the input current (Ii), and second feedback means (26) responsive to the load voltage (Eo) rising above a predetermined level for taking control of the duty cycle of the pulse width modulator (6), said second feedback means (26) having a relatively short time constant for more tightly regulating the load voltage (Eo) in those instances where such voltage rises above said predetermined level.

FIG.1



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(71) Applicant: International Business Machines Corporation
Old Orchard Road
Armonk, N.Y. 10504(US)

(72) Inventor: Carroll, Lawrence B.
629 Sunset Drive
Endwell, N.Y. 13760(US)
Inventor: Willis, Scott C.
606 Barnes Ave.
Endicott, N.Y. 13760(US)

(74) Representative: Gaugel, Heinz, Dipl.-Ing.
IBM Deutschland GmbH Schönaicher
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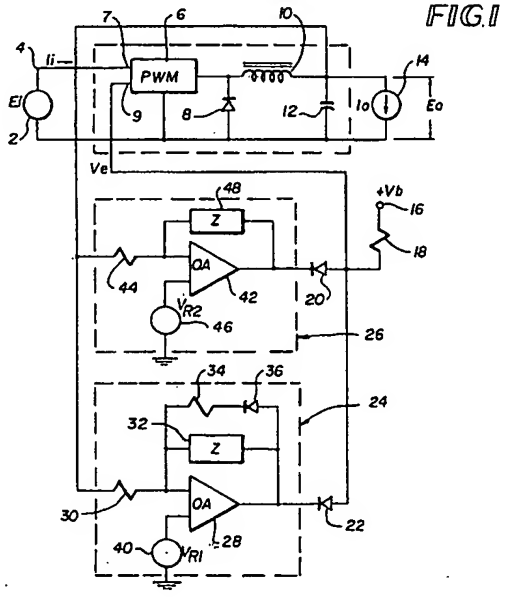
FIG.1



EP 0 473 925 A3

The present invention is directed to switching power supplies, and particularly to improved voltage regulating apparatus for such power supplies.

For many applications, it is important to keep rapid changes in the load current which is provided by a regulated power supply from being reflected back to the input current. For example, such an application is when a three phase source is used to power single phase equipment. In such an arrangement, the output of the three phase source may be rectified, and then converted to single phase A.C. It is important in such an application to approximately equalize the phase currents at the input, so that a fuse or circuit breaker is not opened on one of the input lines when excessive current flows in it.

In order to prevent rapid changes in load current from being reflected to the input in a buck switching type regulator, the feedback loop may be arranged to be relatively slow. This arrangement will have the effect of spreading any reflection of load current changes into the input over several A.C. cycles. Thus, in the case where a three phase input is used, changes in the load current will be averaged over the three phases, rather than having a pronounced effect on any one phase.

However, when a relatively slow feedback loop is used, the voltage regulation at the load suffers to a certain extent. While such a feedback loop provides adequate regulation under most operating conditions, if the load voltage should rise rapidly, the feedback loop may not follow fast enough to prevent damage to a circuit component.

It is to the solution of this problem which the present invention is directed.

It is thus an object of the invention to provide a power supply apparatus wherein rapid changes in the load current are not reflected in the input current.

It is a further object of the invention to limit the maximum value of the load voltage to a predetermined level.

In accordance with the invention, a switching power supply is provided wherein the input current is pulse width modulated by a modulator having a controllable duty cycle. The output of the modulator is filtered to eliminate the high frequency modulation component, and the output is applied to a load. A first feedback loop having a relatively long time constant and a relatively low gain is provided between the load voltage and an input of the pulse width modulator for controlling the duty cycle thereof. Additionally, a second feedback loop which has a shorter time constant and greater gain is provided, and is arranged to take over control when the output voltage attains a predetermined level. In accordance with the invention, the circuit is arranged so that the first feedback loop controls during normal operation with the effect that rapid changes in load current ar not reflected to the input during such operation, while the second feedback loop controls when the output voltage exceeds a predetermined level, and is operative to limit the voltage to such level.

The invention will be better understood by referring to the accompanying drawings, wherein:

Fig. 1 is a circuit diagram of an embodiment of the invention.

Fig. 2 shows the three phase arrangement which may be used as an input to the circuit of Fig. 1.

Referring to Fig. 1, a D.C. voltage source 2 which provides input voltage Ei and input current Ii is shown. This current is fed to input 7 of pulse width modulator 6, which has a controllable duty cycle as determined by feedback voltage Ve, which is fed to input 9. Switching power supplies which include a feedback controlled pulse width modulator for introducing regulation are well known, and for example, such an arrangement is shown in detail, in U.S. Patent No. 3,737,755.

The output of the pulse width modulator is fed to a low pass filter comprised of inductor 10 and capacitor 12, which removes the modulation frequency. Additionally, free wheeling diode 8 is provided, so as to maintain continuous current in inductor 10.

The circuit is loaded by current source 14, which is disposed across capacitor 12, and the load voltage Eo is fed to feedback loops 24 and 26, which determine the control voltage Ve which is fed to input 9 of pulse width modulator 6 to control the duty cycle thereof.

In accordance with the invention, feedback loop 24 controls under normal operating conditions, and this loop is arranged to have a relatively long time constant and a relatively low loop gain. The reason for this is to prevent rapid changes in the output current Io from being reflected into the input current Ii. Thus, with a relatively slow loop, a rapid change in Io will be averaged over several cycles of Ii. With such an arrangement, the capacitor 12 sources and sinks the changes in load current, and regulation of the load voltage is adequate under most operating conditions.

However, when the load voltage rises rapidly, the regulation which is provided by loop 24 may not be fast enough to prevent damage to circuit components, and it is thus necessary to prevent the load voltage from rising above a predetermined level. In accordance with the invention, this is accomplished by using a second feedback loop 26, which takes over control when the load voltage rises to the predetermined level. The second feedback loop has a faster response and higher loop gain then the first loop, and thus quickly regulates the load voltage, so as to prevent it from rising to

5. The apparatus of anyone of the claims 1 to 4 wh r in a referenc voltage (V_{R1}, V_{R2}) is fed to each operational amplifier means (28, 42), and wherein the reference voltage ((V_{R1}) which is fed to the operational amplifier means (28) which is included in the first feedback means (24) has a smaller value than the reference voltage (V_{R2}) which is fed to the operational amplifier means (42) which is included in the second feedback means (26), and wherein the reference voltage (V_{R2}) which is fed to the operational amplifier (42) in the second feedback means (26) corresponds to said predetermined voltage level.

6. An apparatus for providing regulated direct current (Io) from a three phase alternating current source, comprising,

a three phase power source (70) which provides three phase input currents,

a three phase rectifier (72) connected to said power source (70) for providing a direct current (Ii),

means (6) having a controllable duty cycle for pulse width modulating the direct current (Ii) at a preselected frequency,

filter means (10, 12) connected to the output of the means (6) for pulse width modulating, which removes the preselected frequency,

a load connected to the output of the filter means (10, 12), a load voltage (Eo) appearing thereacross,

first feedback means (24) responsive to the load voltage (Eo) for controlling the duty cycle of the pulse width modulator (6) so as to regulate the load voltage, said first feedback (24) means having a relatively long time constant so that changes in the load current (Io) are not rapidly reflected in the three phase input currents, and

second feedback means (26) responsive to the load voltage (Eo) rising above a predetermined level for taking control of the duty cycle of the pulse width modulator (6), said second feedback means (26) having a relatively short time constant for more tightly regulating the load voltage in those instances where such voltage rises above said predetermined level.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 11 2383

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	FR-A-2 433 852 (LUCAS) * page 1, line 34 - page 4, line 17 *	1,6	H02M3/156
A	WO-A-8 604 189 (MOTOROLA) * page 7, line 24 - page 8, line 35 *	1,6	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 MARCH 1992	BERTIN M.H.J.

CATEGORY OF CITED DOCUMENTS

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